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Manipulating the Geometric Computer-aided Design of the Operational Requirements-based Casualty Assessment Model within BRL-CAD

by Joshua Baker and Eric Murray

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14. ABSTRACT
This report outlines how to manipulate the Operation Requirements-based Casualty Assessment geometric model within BRL-CAD and includes best practices for overlap removal. It is written for those already versed in basic BRL-CAD use and commands.

15. SUBJECT TERMS
geometry, conversion, BRL-CAD, ORCA, MUVES

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1.   Introduction

The Operation Requirements-based Casualty Assessment (ORCA) model is used for modeling personnel vulnerability and injury metrics within the MUVES vulnerability/lethality (V/L) analysis environment. The interface between the geometric model and the vulnerability model has specific requirements that must be followed to ensure the proper geometric representation of the ORCA personnel. This report discusses the process to manipulate the ORCA 3-D geometric model for use in BRL-CAD and MUVES. For further detail on the development of ORCA and its uses, reference the *ORCA within MUVES-S2 Analyst Guide and User Manual*.[1]

The ORCA geometric model is maintained by the Ground Mobile Branch Target Modeling Team. Updates to the model are conducted as needed, with the most current model being *orca_ppe_2-23-2017.g* at the time of this report's publishing.

The **dbconcat** command can be used to incorporate ORCA geometry (Fig. 1) into an existing database. This command also has the functionality of prefixing imported names, allowing for the addition of multiple, unique ORCA geometries. When using **dbconcat** ensure that the file is placed in the current directory: type `pwd` from the MGED command line to determine the current directory. You can use the **cd** command to change directories.
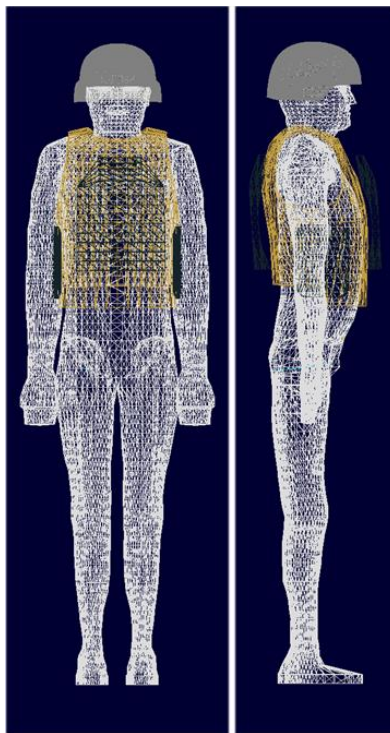

Fig. 1   ORCA geometry

2. Articulating the ORCA Geometric Model

The ORCA geometric model can be manipulated into any posture; however, it must reference the original, unedited configuration when calculating injury insults. Because of this requirement, the ORCA geometric model manipulations must be preserved within the hierarchy as transformation matrices. Thus, the MGED **push** command should never be used on the ORCA geometry.

When placing the ORCA geometric model within a target description, the top-level group (orca_system) should be translated and rotated using a matrix edit to achieve proper location and orientation and to ensure that the entire personnel CAD remains intact. To enter matrix edit mode,[1] draw ORCA at the orca_system level and type the following command:

```
oed / orca_system/orca_man/head/head.r/head.s
```

Manipulating the extremities is accomplished by rotation(s). It is essential that the correct geometric element and the correct location within the hierarchy is selected. Rotational values are expressed as X, Y, and Z axis components with degrees as the unit. There should never be matrices below the region level (to checklist out each region and make sure no matrices are present).

To manipulate the inner extremities (hips/upper legs or shoulders/upper arms), the arms and legs must be rotated in their entirety but independently from each other (rotate the entire left arm, then the right arm, but never the arms together). To appropriately rotate the arms and legs, matrix edit each arm and leg and use the pivot solids found in hips and shoulders as the reference solids. With orca_system drawn on the screen, type one of the following:

```
oed orca_system/orca_man/arms left_arm/shoulder_l/shoulder_l.r/shoulder_pivot_l.s
oed orca_system/orca_man/arms right_arm/shoulder_r/shoulder_r.r/shoulder_pivot_r.s
oed orca_system/orca_man/legs left_leg/hip_l/hip_l.r/hip_pivot_l.s
oed orca_system/orca_man/legs right_leg/hip_r/hip_r.r/hip_pivot_r.s
```

To manipulate the outer extremities (lower arms or lower legs), perform a matrix edit at the group level using the solid as the reference solid. To manipulate the left lower arm, use lower_arm_l.s as the reference solid and place the matrix above the lower_arm_l level. This can be accomplished by drawing ORCA at the orca_system level and using the first command (all 4 commands for outer extremity manipulation listed for reference):

```
oed orca_system/orca_man/arms/left_arm lower_arm_l/lower_arm_l.r/lower_arm_l.s
oed orca_system/orca_man/arms/right_arm lower_arm_r/lower_arm_r.r/lower_arm_r.s
oed orca_system/orca_man/legs/left_leg lower_leg_l/lower_leg_l.r/lower_leg_l.s
oed orca_system/orca_man/legs/right_leg lower_leg_r/lower_leg_r.r/lower_leg_r.s
```

To remove a matrix, either perform the matrix transformation in reverse or access the group above the matrix in the combination editor (found at **Edit** > **Combination Editor**). ORCA model articulation is shown in Fig. 2.
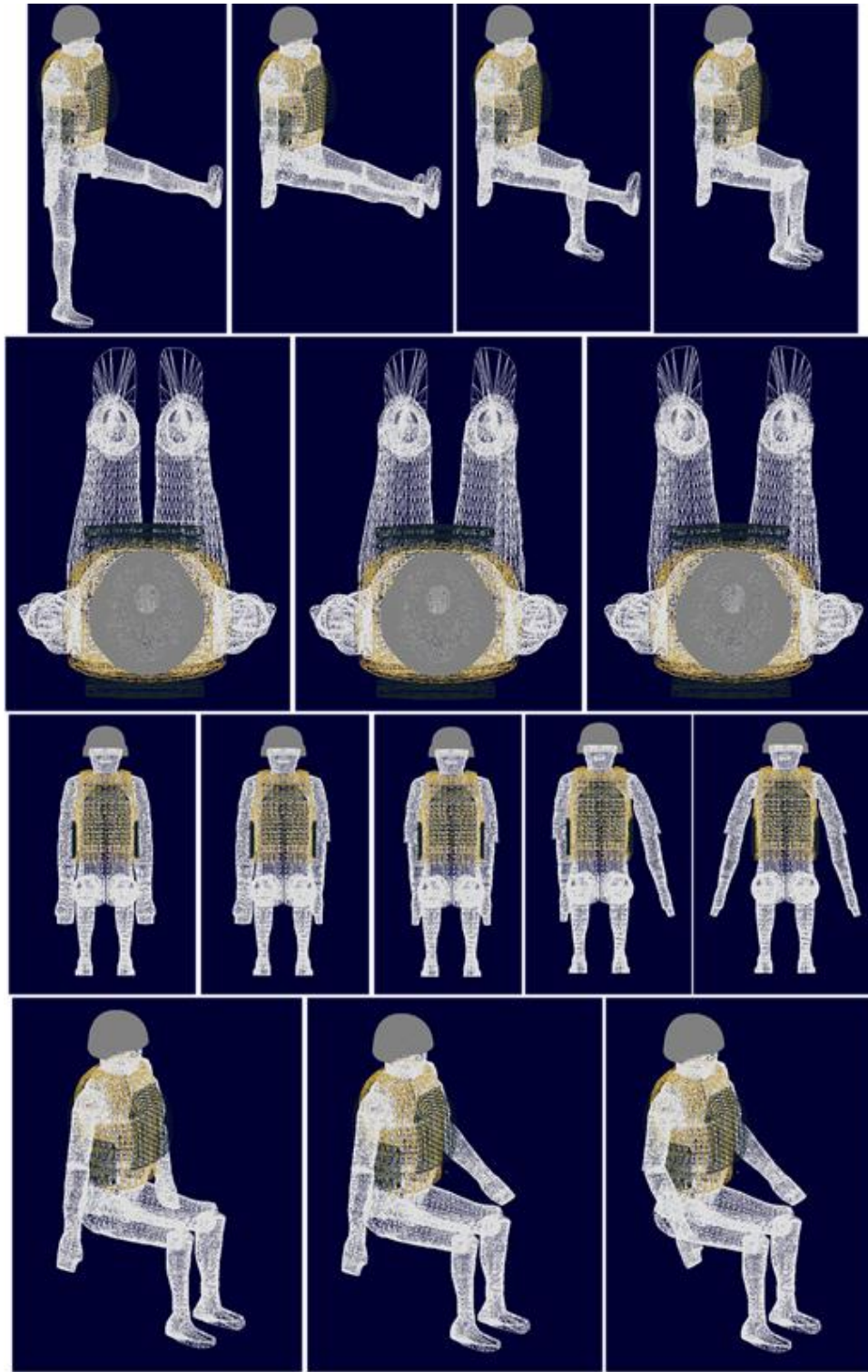

Fig. 2   Progression of articulation

3.   Scaling the ORCA Geometric Model

Because the ORCA geometric model must be passed between MUVES and ORCA, it cannot be scaled in the traditional way. Scaling the ORCA Man in each direction separately ensures that the scaling information is properly captured in the matrix that is passed between MUVES and ORCA, as follows:

1) Draw ORCA Man at the orca_system level.

2) Matrix select ORCA Man at the orca_system level using the following command:

```
oed / orca_system/orca_man/head/head.r/head.s
```

3) Use the **oxscale** command to scale in the x directions (type `oxscale <enter> sca .9<enter>` to scale by 0.9 in the x only).

4) Accept the edit.

5) Repeat, but scale Y then Z using the **oyscale** and **ozscale** commands, respectively (the order of dimension scaling is not important, but must be the same scaling factor in each direction).

6) To check: list ORCA Man at the orca_system level and ensure all matrices are denoted with "scale 1" at the end of the matrix description.

The following is a script to scale ORCA Man by 95%:

```
oed / orca_system/orca_man/head/head.r/head.s

oxscale

sca .95

accept

oed / orca_system/orca_man/head/head.r/head.s

oyscale

sca .95

accept

oed / orca_system/orca_man/head/head.r/head.s

ozscale

sca .95

accept
```

4.   Removing ORCA Geometric Overlaps

The matrices present at various levels in the ORCA hierarchy make overlap removal a challenge. A script has been created to remove the overlaps that are often created during articulation, as follows:

1) Once ORCA Man is placed, run the script in Section 5 to create Boolean solids and subtract them from the appropriate regions.

2) Draw up ORCA Man and ensure there are no double solids (if he appears to have 3 arms, there is a problem). This can be caused by rotating arms or legs together rather than independently.

3) If you need to re-articulate ORCA Man, remove the Boolean solids, move ORCA Man, and then rerun the script. Removing the Boolean solids requires deleting the solid and removing it from the region. This can be accomplished with the **killall** command (i.e., `killall hip_l.s-bool`).

To remove overlaps (Fig. 3) with ORCA Man and non-ORCA geometry (such as seat cushions), use the following **copyeval** command to create a solid that can be subtracted from the region:

```
copyeval orca_system/orca_man/legs/right_leg/hip_r/hip_r.r/hip_r.s new_solid.s
```
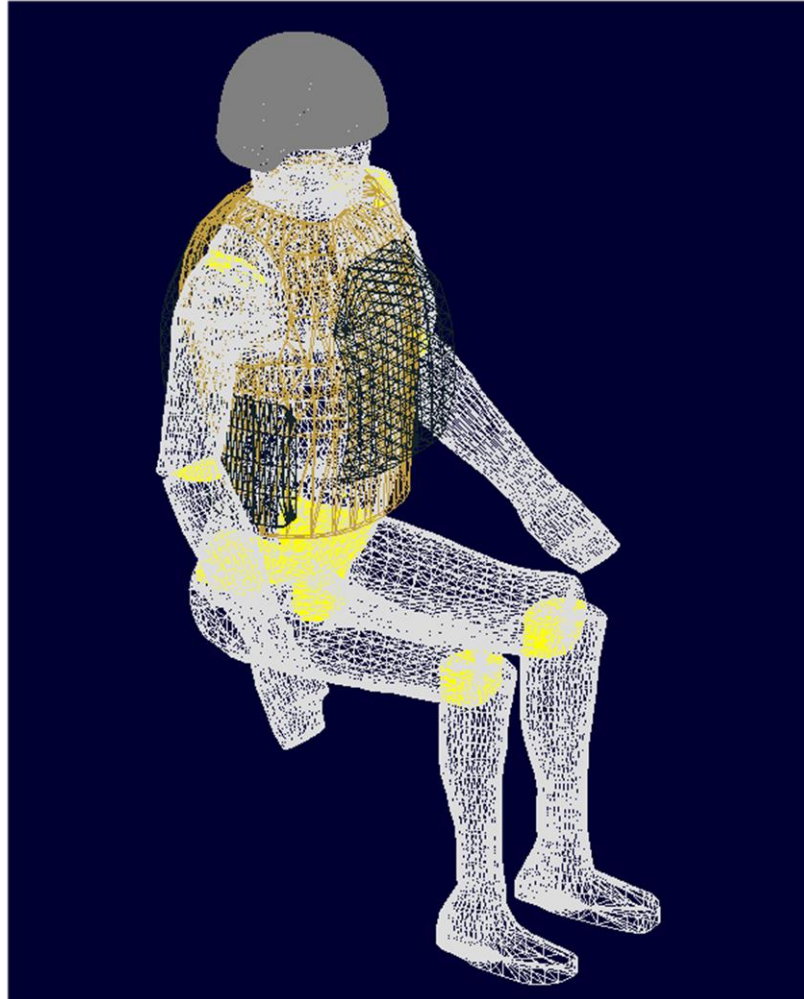
Fig. 3   ORCA overlaps

5.   Sample Script

This script can be placed into a file or simply copy and pasted into MGED, as shown in the following script. You may need to modify the names if you have added prefixes or suffixes to accommodate multiple ORCA Men. The script can be run by typing `source filename.txt` from the mged command line. Ensure that the script is placed in the current directory: type `pwd` from the mged command line to determine the current directory. You can use the **cd** command to change directories.

```
copyeval left_leg/lower_leg_l/lower_leg_l.r/lower_leg_l.s lower_leg_l.s-bool
copyeval right_leg/lower_leg_r/lower_leg_r.r/lower_leg_r.s lower_leg_r.s-bool
copyeval right_arm/lower_arm_r/lower_arm_r.r/lower_arm_r.s lower_arm_r.s-bool
copyeval left_arm/lower_arm_l/lower_arm_l.r/lower_arm_l.s lower_arm_l.s-bool
copyeval legs/left_leg/hip_l/hip_l.r/hip_l.s hip_l.s-bool
copyeval legs/right_leg/hip_r/hip_r.r/hip_r.s hip_r.s-bool
copyeval legs/left_leg/upper_leg_l/upper_leg_l.r/upper_leg_l.s upper_leg_l.s-bool
copyeval legs/right_leg/upper_leg_r/upper_leg_r.r/upper_leg_r.s upper_leg_r.s-bool
copyeval arms/left_arm/shoulder_l/shoulder_l.r/shoulder_l.s shoulder_l.s-bool
copyeval arms/right_arm/shoulder_r/shoulder_r.r/shoulder_r.s shoulder_r.s-bool
copyeval arms/left_arm/upper_arm_l/upper_arm_l.r/upper_arm_l.s upper_arm_l.s-bool
copyeval arms/right_arm/upper_arm_r/upper_arm_r.r/upper_arm_r.s upper_arm_r.s-bool


r upper_leg_l.r - lower_leg_l.s-bool
r upper_leg_r.r - lower_leg_r.s-bool
r upper_arm_r.r - lower_arm_r.s-bool
r upper_arm_l.r - lower_arm_l.s-bool
r pelvis.r - hip_l.s-bool - hip_r.s-bool - upper_leg_l.s-bool - upper_leg_r.s-bool
r thorax.r - shoulder_l.s-bool - shoulder_r.s-bool - upper_arm_l.s-bool - upper_arm_r.s-bool
r otv.r - shoulder_l.s-bool - shoulder_r.s-bool - upper_arm_l.s-bool - upper_arm_r.s-bool
```

6.   Checks

There are a few final checks to perform to ensure that ORCA Man has been placed correctly:

1. Use the **l** command to list out each region and verify that there are no matrices below the region level
2. List ORCA Man's top level group (orca_system or orca_man) and verify that the matrix reads "scale 1."
3. Draw all ORCA regions and confirm that he appears in the standard, unarticulated standing position.

7.   Conclusion

The ORCA geometric model can be manipulated into a wide range of positions, but these manipulations must be performed in a specific manner that allow the regions to be referenced to ORCA Man's original standing position via transformation matrices. Matrices must be placed in the correct hierarchical location and be preserved in the final model. Any scaling must be performed in each coordinate direction independently.

8.   References

1.   Gillich P, Eberius N, Myers T, VanAmburg R. Operational requirement-based casualty assessment (ORCA) within MUVES-S2 analyst guide and user manual. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013 Apr. Report No.: ARL-TR-6416.

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